The National Academies of SCIENCES ENGINEERING MEDICINE

GULF RESEARCH PROGRAM

# Healthy Ecosystems Grants 1 Final Report

**Project Title:** Developing a decision support tool to evaluate ecosystem services and associated uncertainties using a Bayesian belief network
**Award Amount:** $124,342
**Awardee:** University of Southern Mississippi
**Award Start Date:** 11/01/15
**Award End Date:** 04/30/17
**NAS Grant ID:** 2000005979

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**Project Key Personnel:**

- N/A

## I. ORIGINAL PROJECT SUMMARY (from proposal)

A holistic and integrated framework / tool which incorporates multi-disciplinary information and assimilates uncertainties in predictions of ecosystem services is currently lacking but urgently needed to help evaluation of potential risks and trade-offs associated with alternate development and conservation options in a dynamic system, and therefore facilitate more-informed decision making in resource management. The proposed project aims to fill the model/tool gap for the Gulf of Mexico (GOM) and provides a modeling prototype for other regions.

The objective is to develop a holistic modeling framework and decision support tool based on a Bayesian belief network (BBN) for 1) integrated evaluation of ecosystem status under conflicting decisions in ecosystem restoration (coastal wetland restoration) and economic development (offshore drilling), 2) probabilistic predictions of ecosystem services in response to these management decisions, coupled with climate change and sea-level rise, and 3) general assessment of trade-offs of ecosystem services under these interacting drivers. This framework and tool will summarize relevant research evidences from extensive literature review, assimilate uncertainties to reflect complexity of the question and our limited understanding, and have the flexibility and capability to evolve with new knowledge and needs. The broader impact of our study will be to provide an integrated model and tool for answering the questions not only relevant at the GOM but also applicable for many other regions to facilitate more-informed decision making: how will interacting and conflicting decision options in resource conservation / restoration and economic development impact the ecosystem services as a whole? What are the trade-offs of these decisions? How could policy makers adjust these decisions to maximize ecosystem services? It will also lay the foundation of further multi-disciplinary collaboration.

The proposal directly addresses the priorities in the RFA, as it "advances knowledge in ecosystem services related to or influenced by offshore and coastal energy production and their linkages to human well-being" through developing a model and decision support tool that summarizes and assimilates knowledge in multi-disciplines, and generates probabilistic predictions with uncertainties accounted for ecosystem status and services under alternate management and climate scenarios. It also "expands and accelerates the application of ecosystem services to the management and restoration of the Gulf of Mexico and other ecosystems in the outer continental shelf" through the development of the integrated graph-based modeling framework to facilitate communication between scientists and policy makers, evaluation of trade-offs, and prioritization restoration efforts among alternative management options.

The proposal directly supports the Gulf Research Program's two goals: "Goal 2: Improving understanding of the connections between human health and the environment" and "Goal 3: Advance understanding of the GOM region as a dynamic system with complex, interconnecting human and environmental systems, functions, and processes". Its objectives fit in the 2015-2020 objectives of the program, including exploring models of decision support systems, providing research opportunities that improve understanding of how social economic and environmental factors influence community vulnerability, recovery, and resilience, and supporting the development of future professionals and leaders in science policy and community through graduate student and post-doc training.

## II. PROJECT RESULTS

**Accomplishments**

The objective is to develop a holistic modeling framework and decision support tool, which is currently lacking but urgently needed for the northern Gulf of Mexico (NGOM), to 1) evaluate ecosystem status, in particular, coastal wetlands, under climate change and sea-level rise, combined with scenarios of ecosystem restoration and offshore drilling , 2) predict change of ecosystem services with uncertainties accounted for in response to climate drivers and management decisions, and 3) assess trade-offs of ecosystem services under these interacting drivers.

We conducted the following research activities to address the objectives.

1) We predicted coastal wetland loss in response to relative sea-level rise (SLR) and biogeophysical variables at different hydrological regimes for the entire NGOM implementing mixed-effects models. We identified the most important biogeophysical drivers using model selection method.
2) We evaluated wetland ecosystem service values (ESV) based on a world-wide and comprehensive wetland ESV database using meta-regression models.
3) We linked these two models to derive ESV change and their trade-offs based on coastal wetland change under different SLR and management decision scenarios.
4) We packaged the coupled models with different scenarios and database management system (DBMS) into a web-based decision support tool. This tool allows for the selection of any combination of these scenarios to predict changes in wetland areas and ESV.

We described the research activities and main results in more detail as follows:

Research activity 1

We developed mixed-effects models using Bayesian inference. The covariates in the models are spatially explicit geomorphic (coastal slope), physical (tidal range, wave height, SLR), and vegetation variables (normalized difference moisture index NDMI). We created codes to automatically generate models with all possible combinations of these variables. For some models, we divided the NGOM into two hydrological regimes (Louisiana influenced by the Mississippi River and the rest of the NGOM), and assumed that the effect of some/all the covariates on wetland loss differed between the two hydrological regimes. We selected the best model based on predictive posterior loss.

At one highly vulnerable coastal wetland with limited freshwater and sediment inputs in the NGOM – Grand Bay National Estuarine Research Reserve (NERR, 30˚25'47.3''N, 88˚25'39.8''W) where the data for vegetation biomass, sediment concentration in water columns, and sediment accretion rates are available, we developed a mechanistic model to predict wetland change under SLR. This model incorporated hydrodynamic, geomorphological, and ecological processes, which are important drivers for elevation change at wetland platform, and therefore wetland change. Due to the complexity and high data requirement, the mechanistic model is difficult to implement at broader spatial scales like the entire NGOM. However, it provides robust predictions.

We removed coastal slope and wave height from the final models due to their high correlation with SLR. In the final models, SLR, tidal range, and NDMI are three significant factors in affecting wetland loss. The higher the SLR, the larger the wetland loss. We also found that tidal range was an important factor in driving wetland change over the entire NGOM, irrespective of relative sea-level rise rates. On the contrary to what is generally believed – wetland is more resilient to SLR with higher tidal range, we found higher tidal range in Louisiana corresponded to less resilient wetlands to SLR. We believe it is because the higher tidal range exposes larger wetland areas to wave action, destabilizing poorly compacted soil and making it more susceptible to mechanical wetland loss. In-situ vegetation productivity, as represented by NDMI in our model, proved to be important in reducing wetland loss at both site and regional scales from the mechanistic and statistical models. We also identified three locations where there existed high SLR but low wetland loss. The outlier locations corresponded with restoration projects, which we used to form the scenario of wetland restoration.

Research activity 2

We performed Bayesian meta-regression based on 254 studies which examined a variety of ecosystem services of coastal wetlands; twenty-six of the studies were located in the NGOM. We used the ESV meta-regression as the final calculation for ESV change for given changes in wetland area as predicted by the statistical model.

We also examined the regional differences in the valuation of certain ecosystem services. The region was determined based on continents and economic status inferred from the GDP and night-time light intensity from satellite images. We found food (in respect to fisheries) was the only ecosystem service that significantly differed among the regions.

Research activity 3

We evaluated change in coastal wetlands and ESV under different SLR and management scenarios. The SLR scenarios are based on the research by Horton et al. (2014). The management scenarios include

offshore drilling activities and wetland restoration projects. Wetland restoration scenarios are based on current successful restoration projects (assuming increase of NDMI). For the scenario of promoting offshore drilling, we considered the subsidence surrounding offshore oil rigs and the impact of oil spills on both vegetative productivity and human perception of ecosystem services. We used subsidence information in literature as a scenario for offshore oil drilling rig-induced subsidence. We reflected the direct impact of oil spills on ecosystem status by creating a scenario with reduced vegetative productivity measured by reduction in NDMI. We included the indirect impact of oil spills on human perceptions of ecosystem services – particularly the consumption of NGOM seafood. Through collaboration with social scientists from University of Southern Mississippi and University of Southern Alabama, we determined a reduction in ESV for fisheries via the loss of seafood sales and consumption.

Research activity 4

We managed the data using PostgreSQL DBMS. We designed the database in third normal form, using Site-ID as the primary key. We developed a web-based decision support tool which integrated the coupled models with the DBMS and different scenarios using R Shiny application, a web interface between users' browsers and the software R. As users select various scenarios on our web-based applet, computations are done in real-time to provide predictions on changes in wetland area and ESV.

Reference: Horton, B.P., Rahmstorf, S., Engelhart, S.E. & Kemp, A.C. (2014). Quat. Sci. Rev. 84, 1–6.

**Initial Outcomes**

The implications of the project results for other current and any future work of the project team, and for the research or practices of others include:

1. Two-step approach is a computationally efficient way to predict ecosystem change under SLR for the entire northern Gulf of Mexico (NGOM). The first step is to develop a statistical model for the entire study area, and the second step is to collect necessary biogeophysical data at the highly vulnerable wetlands and implement a mechanistic model for more robust predictions of wetland change at those wetland loss hotspots.
2. It is important to account for uncertainties in predictions.
3. It is important to account for multiple interacting drivers simultaneously, coupled with climate change and management decisions scenarios in ecological predictions.
4. It is important to involve end users as early as possible for the development of decision-support tools.
5. The project created an opportunity of collaboration between natural and social scientists through a SESYNC funded workshop Computational Summer Institute, Annapolis, MD, July 26-29, 2016. We learned the language barrier in interdisciplinary studies could come from different definitions of the same terms in different disciplines, therefore having the definitions of key words stated out will greatly facilitate conversations. The multidisciplinary collaboration will continue in the future.

Why are your results important to science or society?

The modeling framework and decision support tool developed in this study summarized relevant research evidences from extensive literature review, assimilated uncertainties to reflect complexity of the question and our limited understanding, and had the flexibility and capability to evolve with new

knowledge and needs. The broader impact of our study will be to provide an integrated model and tool, readily accessible for the general public and policy makers, for answering the questions not only relevant at the NGOM but also applicable for many other regions to facilitate more-informed best-practice decision making: how will interacting and conflicting decision options in resource conservation / restoration and economic development impact the ecosystem services as a whole? What are the trade-offs of these decisions? How could policy makers adjust these decisions to maximize ecosystem services? It will also lay the foundation of further multi-disciplinary collaboration.

**Unexpected Results**

1. Higher tidal range decreases the resilience of coastal wetlands to SLR. We expected the opposite as in the literature. In fact, the result is reasonable. The entire northern Gulf of Mexico is micro-tidal system. The slightly larger tidal range in Louisiana exposes large wetland areas to wave action, destabilizing poorly compacted soil and making it more susceptible to mechanical wetland loss.
2. Food (in respect to fisheries) was the only ecosystem service that significantly differed among continents and economic status. We expected a suite of ecosystem services differed among continents and economic status due to different culture and perceptions on ecosystem services.

**Project Relevance**

Researchers, educators, community leaders, state government officials, and federal government officials would be interested in the results of this project.

Researchers are interested in our research results because the results synthesize current research evidence, account for uncertainty in predictions, and show a useful tool with flexibility and capability to evolve with new knowledge and needs.

Educators are interested in our research results because they can utilize the web-based decision support tool to demonstrate how SLR and climate change, coupled with real-world management decisions, could affect coastal ecosystems, in an interactive and clear way to students. In fact, we demonstrated a beta version of the web-based decision support tool to the 6th graders in Ocean Springs on Earth Exploration Day, Ocean Springs, MS, November 18, 2016, and generated great curiosity and interests on the SLR impact among those students.

Community leaders and state/federal government officials are interested in our research results because they can utilize the decision support tool to evaluate the impact of different management scenarios, coupled with SLR and climate change scenarios, on coastal ecosystems and ecosystem services. This allows for site-specific resource managers to evaluate the best management plan for their area in respect to ecosystem service values. We demonstrated the tool to Mr. George Ramseur, who is in charge of beneficial use program from the Department of Mississippi Marine Resource, at the 2017 Oil Spill and Ecosystem Science Conference, February 8, 2017. Mr. Ramseur showed great interests in learning the tool more when it is fully functioning.

**Education and Training**

Number of students, postdoctoral scholars, or educational components involved in the project:

- Undergraduate students: 1
- Graduate students: 1
- Postdoctoral scholars: 0
- Other educational components: 1

We presented the impact of sea-level rise on coastal environment and demonstrated a beta version of the web-based decision support tool to the 6th graders in Ocean Springs on Earth Exploration Day, Ocean Springs, MS, November 18, 2016. The outreach activity generated great curiosity and interests on sea-level rise impact among the students.

## III. DATA AND INFORMATION PRODUCTS

This project produced data and information products of the following types:

- Data
- Scholarly publications, reports or monographs, workshop summary or conference proceedings
- Websites or data portals
- Curricula for education and training
- Models and simulations
- Software packages, digital tools, or other interactive media

### DATA

See attached Data Report.

**Relationships between data sets:**

The file "inlandbuff.shp" is the geospatial component that relates to the other datasets. Each buffered coastal zone in inlandbuff.shp is referenced by the primary key 'ORIG_FID' which indicates buffer ID. All other datasets (wetloss.txt, NDMI.txt, discharge.txt, and geomorph.txt) contain the primary key 'ORIG_FID'. Joins can occur on 'ORIG_FID' to associate variables with geospatial buffered coastal zone.

The "TEEB-NoBT-USD2007.txt" is the data for ecosystem services of coastal wetlands worldwide collected from extensive literature review. It will be linked to "wetloss.txt", "worldPop.txt" and "worldGDP2010.txt" through primary key of 'ORIG_FID" which indicates ID for each study site.

All of these files are hosted on the USM Landscape Ecology Database server in the database 'NAS_postgis' (third normal form).

**Other activities to make data discoverable:**

1) Worked with ITech at the USM, preparing to host the decision support tool on our lab website: ecospatial.usm.edu
2) Talked to decision makers who are potential end users of the tool developed for this project.
3) Presented research results at the scientific conferences.
4) Wrote manuscripts for scientific publications.
5) Conducted outreach activities to publicize our web-based decision support tool.

### INFORMATION PRODUCTS

**Citations for project publications, reports and monographs, and workshop and conference proceedings:**

1. Wu, W., P.D. Biber, M. Bethel, submitted to Ecology Letters. Thresholds of sea-level rise rate and sea-level acceleration rate in a vulnerable coastal wetland.
2. Hardy, T., W. Wu. Spatial variability of the resilience of coastal wetlands to sea-level rise in the northern Gulf of Mexico using Bayesian inference. Will submit it to Journal of Geophysical Research in June 2017.
3. W. Wu, P. Biber, M. Bethel. Thresholds of sea-level rise for vulnerable coastal wetlands. International Association of Landscape Ecology Annual Symposium, Baltimore, MD, April 12, 2017. (Oral, contributed, international, abstract published)
4. W. Wu, M. Bethel, P. Biber. Thresholds of sea-level rise on coastal wetlands. Bays and Bayous Symposium, Biloxi, MS, November 30, 2016. (Oral, contributed, regional, abstract published)
5. T. Hardy (student supported by the project), W. Wu. Evaluating wetland loss as a function of relative sea-level rise, biological, hydrological, and geomorphic characteristics for the northern Gulf of Mexico using Bayesian inference. Bays and Bayous Symposium, Biloxi, MS, November 30, 2016. (Oral, contributed, regional, abstract published)
6. W. Wu, K. Yeager, M. Peterson, R. Fulford, T. Hardy (student). Evaluating the SLAMM using neutral models. The International Society for Ecological Modelling Global Conference, Towson University, Baltimore, MD, May 9, 2016. (Oral, contributed, international, abstract published)
7. W. Wu, T. Hardy, 2016. Progress report.
8. W. Wu, T. Hardy, 2017. Final report.

**Websites and data portals:**

1. http://wulab.shinyapps.io/DecisionSuppTool
2. http://wulab.shinyapps.io/osuewetlands
3. http://github.com/tylerthardy/NAS_2016 (currently private)
4. http://ecospatial.usm.edu

We will maintain the first website for another five years after the project ended. We will transfer the tool to my lab website (ecospatial.usm.edu) and maintain it for long-term. We will archive our data and models at the journal website where we publish the research results. We will archive our model at the NCEAS.

**Information Product Inventory:**

See attached Information Products Report.

**Other activities to ensure access to information products:**

1. Worked with ITech at the USM, preparing to host the decision support tool on our lab website: ecospatial.usm.edu
2. Talked to decision makers who are potential end users of the tool developed for this project.
3. Presented research results at the scientific conferences.
4. Wrote manuscripts for scientific publications.
5. Conducted outreach activities to publicize our web-based decision support tool.

| Data Report | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **DataType** | **DigitalResourceType** | **Title** | **FileName** | **Creators** | **PointofContact** | **PublicationYear** | **RepositoryName** | **DOIorPersistentURL** | **Keywords** | **Publications** |
| Geospatial | Geospatial (vector, raster, or gridded) | NGOM Inland Coastal Buffers | inlandbuff.shp inlandbuff.dbf inlandbuff.prj inlandbuff.shx | Hardy, Tyler | tyler.t.hardy@usm.edu 908-399-1612 | 2016 | USM Landscape Ecology Database | 52.14.87.100:5432, database=NAS_postgis, table=inlandbuff | NGOM, coast, coastline, NGOM coast, Gulf of Mexico, Gulf of Mexico coast, GOM, GOM coast, ORIG_FID | |
| Ecological/Biological | Tabular/Spreadsheet | Wetland Loss at Coastal Buffers and Wetland Areas Which Have ESV | wetloss.txt | Hardy, Tyler | tyler.t.hardy@usm.edu 908-399-1612 | 2016 | USM Landscape Ecology Database | 52.14.87.100:5432, database=NAS_postgis, table=wetloss | NGOM wetland loss, GOM wetland loss, GOM wetland, GOM, wetland, wetland loss, ORIG_FID, Gulf of Mexico | |
| Ecological/Biological | Tabular/Spreadsheet | Normalized Difference Moisture Index (NDMI) at Coastal Buffers | NDMI.txt | Hardy, Tyler | tyler.t.hardy@usm.edu 908-399-1612 | 2016 | USM Landscape Ecology Database | 52.14.87.100:5432, database=NAS_postgis, table=ndmi | NGOM NDMI, GOM NDMI, normalized difference vegetation index, vegetation index, remote sensing, vegetation, NGOM vegetation, GOM vegetation, Gulf of Mexico, ORIG_FID | |
| Earth and Environmental Sciences | Tabular/Spreadsheet | Riverine Discharge | discharge.txt | Hardy, Tyler | tyler.t.hardy@usm.edu 908-399-1612 | 2016 | USM Landscape Ecology Database | 52.14.87.100:5432, database=NAS_postgis, table=discharge | NGOM rivers, NGOM river, GOM rivers, GOM river, river, NGOM dishcharge, GOM discharge, river discharge, discharge, allocthonous, ORIG_FID, Gulf of Mexico | |
| Earth and Environmental Sciences | Tabular/Spreadsheet | Geomorphic Characteristics (THK99) at Coastal Buffers, including sea-level rise, tidal range, coastal slope, wave height | geomorph.txt | Hardy, Tyler | tyler.t.hardy@usm.edu 908-399-1612 | 2016 | USM Landscape Ecology Database | 52.14.87.100:5432, database=NAS_postgis, table=thk99 | RSLR, SLR, relative sea level rise, relative sea-level rise, sea-level rise, sea level rise, tidal range, tides, coastal slope, slope, wave height, waves, ORIG_FID, Gulf of Mexico | |
| Economic | Tabular/Spreadsheet | World Coastal Ecosystem Service Values | TEEB-NoBT-USD2007.txt | Hardy, Tyler | tyler.t.hardy@usm.edu 908-399-1612 | 2016 | USM Landscape Ecology Database | 52.14.87.100:5432, database=NAS_postgis, table=esv | ESV, ES, ecosystem service, ecosystem service value, ecosystem service values, fisheries, oil production, food, protection, ecosystem | |
| Social/Cultural | Tabular/Spreadsheet | Country Populations of the World - WorldBank | worldPop.txt | Hardy, Tyler | tyler.t.hardy@usm.edu 908-399-1612 | 2016 | USM Landscape Ecology Database | 52.14.87.100:5432, database=NAS_postgis, table=pop | world population, country population | |
| Economic | Tabular/Spreadsheet | World GDP - CIA | worldGDP2010.txt | Hardy, Tyler | tyler.t.hardy@usm.edu 908-399-1612 | 2016 | USM Landscape Ecology Database | 52.14.87.100:5432, database=NAS_postgis, table=gdp | world GDP, GDP, gross domestic product, country GDP | |

**Information Products Report**

| InfoProductType | DigitalResourceType | Title | FileName | Creators | PublicationYear | Publisher | RepositoryName | DOIorPersistentURL | DatasetReference |
|---|---|---|---|---|---|---|---|---|---|
| Report or Monograph | Text | Progress Report | ProgressReport.docx | Wu, Wei; Hardy, Tyler | 2016 | USM Landscape Ecology Exploratory NAS Project Respository | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tylerthardy/NAS_2016/blob/master/products/ProgressReport.docx | 52.14.87.100:5432, database=NAS_postgis |
| Report or Monograph | Text | Final Report | FinalReport.docx | Wu, Wei; Hardy, Tyler | 2017 | USM Landscape Ecology Exploratory NAS Project Respository | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tylerthardy/NAS_2016/blob/master/products/FinalReport.docx | 52.14.87.100:5432, database=NAS_postgis; https://github.com/tylerthardy/NAS_2016; http://wulab.shinyapps.io/osuewetlands; http://wulab.shinyapps.io/DecisionSuppTool |
| Scholarly Publication | Text | Thresholds of sea-level rise rate and sea-level acceleration rate in a vulnerable coastal wetland | Thresholds.pdf | Wu, Wei; Biber, Patrick; Bet | 2017 | TBD (submitted to Eco | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tylerthardy/NAS_2016/blob/master/products/Thresholds.pdf | |
| Scholarly Publication | Text | Spatial variability of the resilience of coastal wetlands to sea-level rise in the northern Gulf of Mexico using Bayesian inference | Resilience.pdf | Hardy, Tyler; Wu, Wei | 2017 | TBD (Will submit to Jou | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tylerthardy/NAS_2016/blob/master/products/Resilience.pdf | 52.14.87.100:5432, database=NAS_postgis; https://github.com/tylerthardy/NAS_2016 |
| Workshop or Conference Proceeding | Text | Thresholds of sea-level rise for vulnerable coastal wetlands | Thresholds_IALE.pptx | Wu, Wei; Biber, Patrick; Bet | 2017 | US-IALE 2017 | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tylerthardy/NAS_2016/blob/master/products/Thresholds_IALE.pptx | |
| Workshop or Conference Proceeding | Text | Thresholds of sea-level rise on coastal wetlands | Thresholds_BB.pptx | Wu, Wei; Biber, Patrick; Bet | 2016 | Bays and Bayous Symp | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tylerthardy/NAS_2016/blob/master/products/Thresholds_BB.pptx | |
| Workshop or Conference Proceeding | Text | Evaluating wetland loss as a function of relative sea-level rise, biological, hydrological, and geomorphic characteristics for the northern Gulf of Mexico using Bayesian inference | Resilience_BB.pptx | Hardy, Tyler; Wu, Wei | 2016 | Bays and Bayous Symp | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tylerthardy/NAS_2016/blob/master/products/Resilience_BB.pptx | 52.14.87.100:5432, database=NAS_postgis; https://github.com/tylerthardy/NAS_2016 |
| Workshop or Conference Proceeding | Text | Evaluating the SLAMM using neutral models | SLAMM_EM.pptx | Wu, Wei; Yeager, Kevin; Pet | 2016 | The International Socie | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tylerthardy/NAS_2016/blob/master/products/SLAMM_EM_pptx | |
| Curricula (for education or training) | Web Based Resource | Education Outreach: 'Wetland Loss Estimator' | http://wulab.shinyapps.io/ | Hardy, Tyler; Wu, Wei | 2016 | USM Landscape Ecology Lab Website | USM Landscape Ecology Lab Website | http://wulab.shinyapps.io/osuewetlands | |
| Digital Tools or Other Interactive Media | Web Based Resource | NGOM Oil Production and Restoration Decision Support Tool | http://wulab.shinyapps.io/ | Hardy, Tyler; Wu, Wei | 2017 | USM Landscape Ecology Lab Website | USM Landscape Ecology Lab Website | http://wulab.shinyapps.io | 52.14.87.100:5432, database=NAS_postgis; https://github.com/tylerthardy/NAS_2016 |
| Models and Simulations | Text | Parameter estimation for mixed-effects model for wetland change prediction | 86.Rdata | Hardy, Tyler; Wu, Wei | 2017 | USM Landscape Ecology Exploratory NAS Project Respository | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tyler | 52.14.87.100:5432, database=NAS_postgis; https://github.com/tylerthardy/NAS_2016/blob/master/WetlandModel/models2regions.R |
| Models and Simulations | Software and Source Code | Mixed-effects models for coastal wetland change | models2regions.R | Hardy, Tyler; Wu, Wei | 2017 | USM Landscape Ecology Exploratory NAS Project Respository | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tyler | 52.14.87.100:5432, database=NAS_postgis; https://github.com/tylerthardy/NAS_2016/ |
| Models and Simulations | Software and Source Code | SLR and mangement scenarios | scenarios.R | Hardy, Tyler; Wu, Wei | 2017 | USM Landscape Ecology Exploratory NAS Project Respository | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tyler | 52.14.87.100:5432, database=NAS_postgis; https://github.com/tylerthardy/NAS_2016/ |
| Models and Simulations | Software and Source Code | Meta-regression model for ecosystem service values (GIS application) | ESV.R | Hardy, Tyler; Wu, Wei | 2017 | USM Landscape Ecology Exploratory NAS Project Respository | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tyler | 52.14.87.100:5432, database=NAS_postgis; https://github.com/tylerthardy/NAS_2016/ |
| Models and Simulations | Text | Parameter estimation for meta-regression model for ecosystem service values | ESV.Rdata | Hardy, Tyler; Wu, Wei | 2017 | USM Landscape Ecology Exploratory NAS Project Respository | USM Landscape Ecology Exploratory NAS Project Respository | https://github.com/tyler | 52.14.87.100:5432, database=NAS_postgis; https://github.com/tylerthardy/NAS_2016/ |